Some techniques for the analysis of remote sensing images with particular relevance to their exploitation in non scientific domains

Lucien Wald

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SOME TECHNIQUES FOR THE ANALYSIS OF REMOTE SENSING IMAGES WITH PARTICULAR RELEVANCE TO THEIR EXPLOITATION IN NON SCIENTIFIC DOMAINS

Dr Lucien WALD,
Head of the Remote Sensing Group

Centre de Télédétection et d'Analyse des Milieux Naturels
Ecole Nationale Supérieure des Mines de Paris
Rue Claude Daunesse
Sophia-Antipolis
F-06565 Valbonne Cédex

Abstract

Remote sensing is now a masterpiece in the scientific understanding of the entire Earth system on a global scale which is the goal of the Earth system science for next decades. Remote sensing is also a masterpiece in environmental management since it provides a wealth of information unattainable by traditional means. Some techniques for the analysis of satellite images and their use in scientific domains are presented briefly. Some examples are given, covering meteorology, oceanology, forestry and vegetation studies. This communication focuses itself on the exploitation of such images and techniques in non-scientific domains. The benefit of such data in environmental planning is depicted and is illustrated by a numerical forecasting of regional urban growth. The potential of the use of satellite images by engineering companies is discussed in the light of recent advances in methods and computers. Particular attention is paid to the solar engineering field.

1. INTRODUCTION

Space techniques have opened up an extraordinarily productive avenue for global Earth observations. Recent advances in technology, ranging from sensor development to advanced computing systems, have given us the means to record and analyze the fundamentals processes in nature with unprecedented completeness and detail. Remote sensing is now a masterpiece in the scientific understanding of the entire Earth system on a global scale which is the goal of the Earth system science for next decades. Remote sensing is also a masterpiece in environmental management since it provides a wealth of information unattainable by traditional means.

Ecole des Mines de Paris is one of the major actors in the exploitation of satellite data for Earth sciences, as well as environmental management purposes. As such we develop many techniques for the analysis of satellite images. These data, at the moment, mostly benefit the

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scientific domains. However, large efforts are devoted to make satellite data a daily tool for environmental planners and more generally for the non-scientific community. The daily display on TV screens or in newspapers of satellite image for meteorological forecasting provides the simplest example of it. This communication mostly deals with such approaches. Some examples are given in the field of urban growth planning and solar energy engineering.

Of course, this goal can only be achieved if data are used which come from satellites part of an operational program. This ensures that the same kind of data will be available to the end-user during five to ten years or more, which allows the user to make its investments profitable. SPOT, Landsat, NOAA and Meteosat are examples of such operational programmes. Therefore, we will not deal here with other kind of sensor or of sensing techniques, such as microwave instruments, which have already be flown successfully aboard spacecrafts or are to be launched in the next few years. The accent is here only on current operational programmes.

2. SATELLITE DATA PROCESSING SYSTEMS

Satellite data usually come from the receiving station to the end-user in the form of Computer Compatible Tapes (CCT). These tapes are ingested by a computer and the data are processed by an image processing software. The computing hardware must comprise calculators, image display consoles, tape readers, digitizing means (scanners, tables, cameras, video readers) and color printers. The software may comprise general processing features or can be tailored for a very peculiar application.

Recent advance in computer have allowed equally large advances in making remote sensing a tool of the daily life. Of these advances, the most important ones are the emergence of standards in computer operating systems, peripheral interfaces, communication and software. Therefore, the tools required for the exploitation of satellite data are almost available "on the shelf" and this exploitation needs not specific and very costly pieces of equipment as before.

A recommanded computing configuration is the following : a large 32 bits UNIX computer with large mass storage, such as magneto-optical disk, serves a net of workstations with image display capability (Fig. 1). These workstations are of various types, but still belong to well spread standards. They are based on UNIX computers with X-Windows as graphic standard or on PS or PC micro-computers. Of importance are the capabilities for data inputs and exchanges: magnetic tapes, interface with other nets such as ISDN standard (Integrated Services Data Net), digitizing means, or possibly a satellite receiving station, and, for results mapping : colour printer or photo-engraver.

3. BASIC TECHNIQUES FOR REMOTE SENSING DATA ANALYSIS

Once the data received from a satellite operator and stored onto the computer, some basic techniques must be applied to render them ready to use for peculiar purposes. These techniques are usually independant of the kind of data and deal with calibration, correction of the atmospheric effects and navigation. Calibration procedure changes raw data of the satellite sensor into energy units or temperature data. Then, data must be corrected to take into account the influence of the atmosphere on the signal upcoming from the ground towards the satellite. At last, the satellite image is navigated to establish the geographical coordinates of each pixel within the image.

An example of these techniques is presented in Figure 2, which deals with ocean primary production in the northwestern Mediterranean Sea. The upper figure displays the raw image acquired by the Coastal Zone Color Scanner (CZCS) aboard the Nimbus 7 satellite. Note how the coastal line is deformed and also the presence of atmospheric haze masking the signal

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coming from the interior of the sea. The lower figure shows the atmospherically corrected and navigated image, which now exhibits large meanders denoting deep water formation (Wald *et al.*, 1983).

The satellite images offer two characteristics which can be used separately or together : frequent observations and multispectral bands measurements.

The frequence of acquisition of an image of the same scene depends upon the satellite and sensor. For example, it ranges from half an hour for Meteosat to about fifteen days for SPOT or Landsat. Frequent observations are necessary in meteorology and also in regional studies of the vegetation. In Figure 3 is displayed an image of the albedo of the ground in Egypt. It has been computed from a time-series of navigated, atmosphere-corrected and cloud-decontaminated Meteosat images (Moussu *et al.*, 1989). The albedo is closely related to the vegetation and such albedo images allow the analysis of the state and evolution of the vegetation (Diabaté *et al.*, 1989b). They also permit to monitor drought in Sahel by studying the water level in Lake Chad (see *e.g.* Mohler *et al.*, 1989, or Wald, 1990).

A scanner aboard an Earth observation satellite usually makes multispectral measurements. Multispectral classification is the basic way of mapping from satellite images. Objects within an image are classified according to their likeness to known terrestrial objects in terms of spectral signature. This aspect of remote sensing is widely used in Earth sciences as shown by the colour slides presented during the communication. Figure 4 exhibits such an example dealing with the use of satellite images to map the forest biomass available for energy conversion.

Of course, both aspects (multi-temporal and multi-spectral) are very often used together, and particularly to analyze the evolution of a landscape or a natural process or a pollution. In Figure 5 are presented maps showing oil spills observed over some weeks in 1981 in the Mediterranean Sea (Wald *et al.*, 1984). Such maps indicate that frequent oil discharges from tankers occur close to Sicily, and that the prevention of this pollution should have been enforced for a better protection of the marine and coastal environment.

A special mention must be made about SPOT. Its major characteristic is its capability of providing stereoscopic image pairs of very high resolution for a given region, thus allowing the computation of the relief. This is a very particular aspect of remote sensing, and it proves very successfull in computing digital terrain elevation maps for large areas. When combined to multispectral measurements, such elevation maps greatly improve the accuracy in land use mapping or in photogrammetry.

4. EXPLOITING SATELLITE IMAGES IN NON-SCIENTIFIC DOMAINS : SOME EXAMPLES

Remote sensing images mostly benefit the scientific community, if military intelligence is not taken into account. Large efforts are now devoted to spread the use of satellite data among engineers and planners. The daily display on TV screens or in newspapers of satellite images for meteorological forecasting illustrates these efforts in a simple way.

Ecole des Mines de Paris has always been part of such efforts. Beyond its works on remote sensing softwares to make them more convenient for non-scientific people, it has developed some examples of integrated techniques dealing with satellite images to provide precise answers to engineers and planners in a rather automated fashion. Some of these examples are presented below. Others deal with mineral prospection, forest biomass for energy conversion (Wald, 1987), prevention and fithting of forest fires (Husson, 1982, 1983) and ocean engineering (Bianchi and Wald, 1988 ; Wald *et al.*, 1983 ; Wald, 1985).

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In the first example, satellite images are combined with a numerical model for the simulation of regional urban growth (Méaille and Wald, 1990). The area under study is located in the southeast of France, and is part of the French Riviera (Fig. 6). It represents a square of 40 x 40 km^2, with a pixel of 80 x 80 m^2. Two Landsat Multi-Spectral Scanner (MSS) images were analyzed to provide two maps of land use and urban domain for 1976 and 1981. A numerical model for the growth of the density of the population is applied to the urban domain of 1976 and forecasts the changes until 2025, after it has been calibrated using the satellite-derived map of 1981 (Fig. 6 and 7). The model takes into account some constraints due to the environment as well as the changes in population per city and per year. The environmental parameters were namely land use, topography, road network and forest characteristics. Some of them : land use and forest fire frequency, were mapped from satellite images and the others were digitized from existing maps. However, if used, SPOT would have increased the number of parameters mapped directly from satellite data, as well as the resolution of the maps, by means of stereoscopic and multispectral classification techniques. Nowadays, topography, and thus slopes and exposures, roads network, land use and vegetation types are commonly extracted from SPOT images. Forecastings such as this one are very useful for regional managers and planners, and particularly in areas exposed to large population growth like in the French Riviera. Among other figures, they show the extension of the urban domain from year to year, the spatial patterns of growth and the previous type of land use (kind of agriculture, moor, forest, etc...) of a pixel now urban.

The second example deals with solar energy engineering and is one of the very few turn-key, fully automated existing systems dedicated to the processing of satellite images for a peculiar application. The purpose of the system is to provide solar energy engineers with estimates of solar radiation by processing Meteosat images using a complex image analysis involving atmosphere modelling (Cano *et al.*, 1986 ; Diabaté *et al.*, 1988). Meteosat satellite images are directly received on a cheap receiver coupled to and driven by a personal computer. They are stored on the hard-disk, automatically navigated and displayed onto a colour screen. They are processed according special procedures which compute the solar energy impinging the ground at each pixel of 5 x 5 km^2. This final map is displayed less than one hour after the image reception, and with no operator intervention (Diabaté *et al.*, 1989a). This tool is of great importance because it allows the knowledge of the solar radiation outside the ground stations where measurements are usually available. Therefore, solar energy engineers better calculate the sizing, the efficiency and the performances of planned equipments and plants. It is also of effective profit in the control of the production of electricity by large photovoltaic or water heating solar plants. The low cost of the total system, about 30,000 US $, makes it worth the investment.

5. CONCLUSION

Some techniques for the analysis of satellite images have been presented. Particular attention was paid to their exploitation by engineers and planners. Some examples are given, which show that remote sensing can be a daily tool for the non-scientific community ; but large efforts are still needed. If improvement in software is required, the major effort lies in the close cooperation between the end-user and the remote sensing expert. The expert must understand how the engineer and the planner think, how they process the information they use to deal with, and then he must integrate as smoothly as possible the remote sensing data into the daily life of its partners. This implies of course that meanwhile the expert trains its partners in remote sensing.

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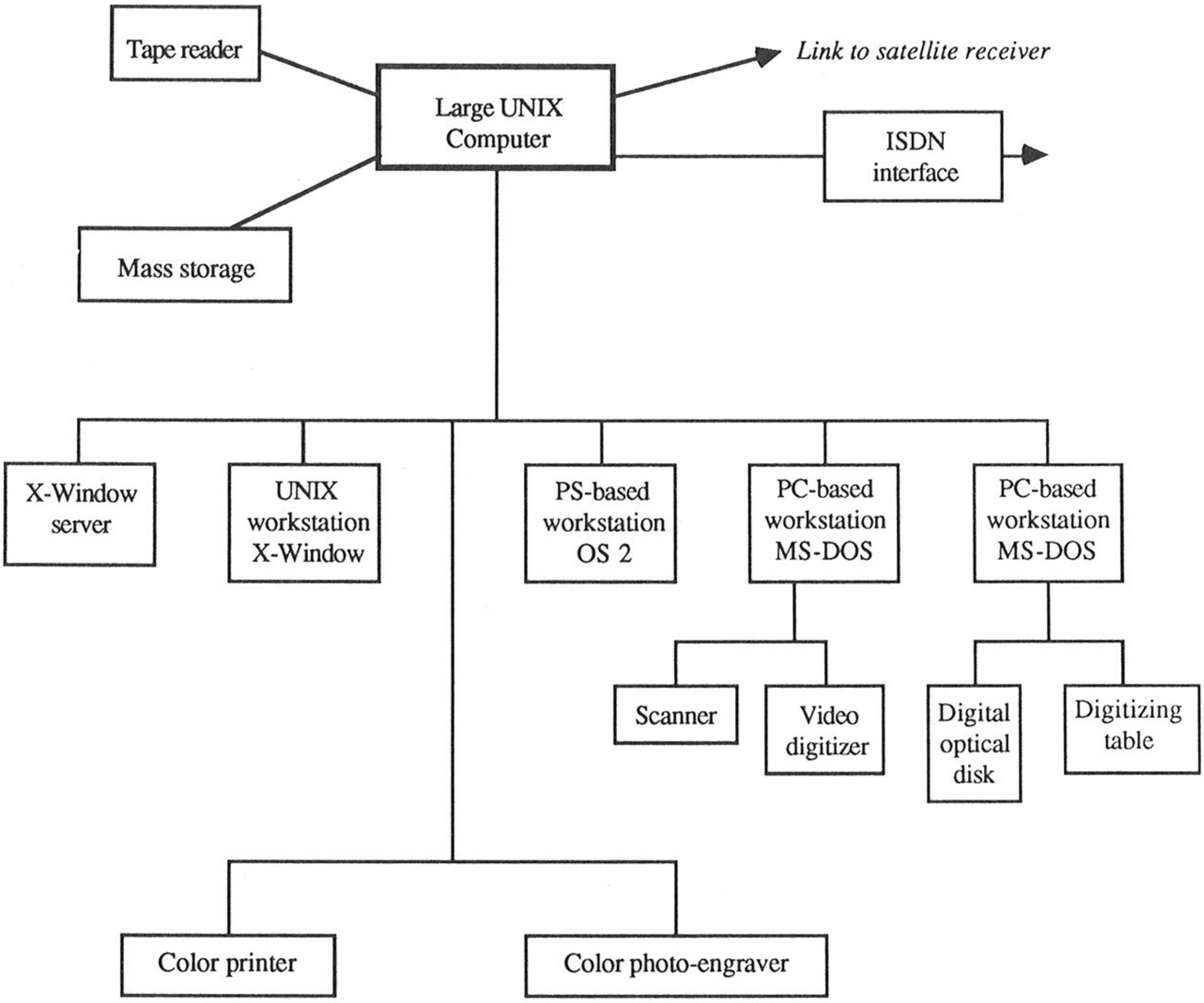

Figure 1 : Example of hardware configuration.

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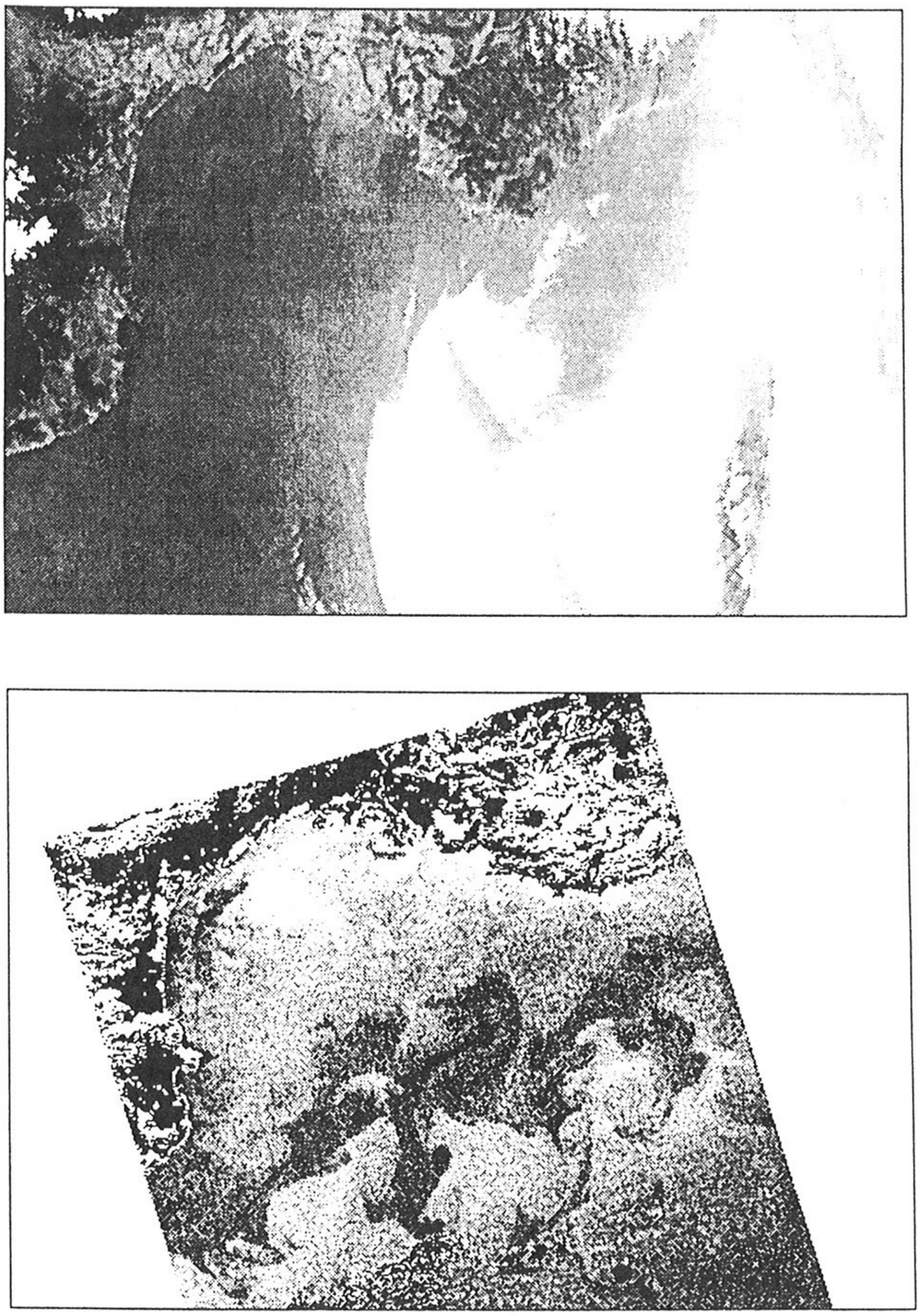

Figure 2 : *Coastal Zone Color Scanner (CZCS) image of the northwestern Mediterranean Sea, February 1, 1981.*
The upper image shows the raw data. Land is in black and grey. Note how it is deformed. Haze is in white. The elongated grey shape on the lower right is the Corsica island.
The lower image displays the data after navigation and removal of atmospheric haze. Land is now in black and white. Note the large meanders in the sea, due to deep-water formation.

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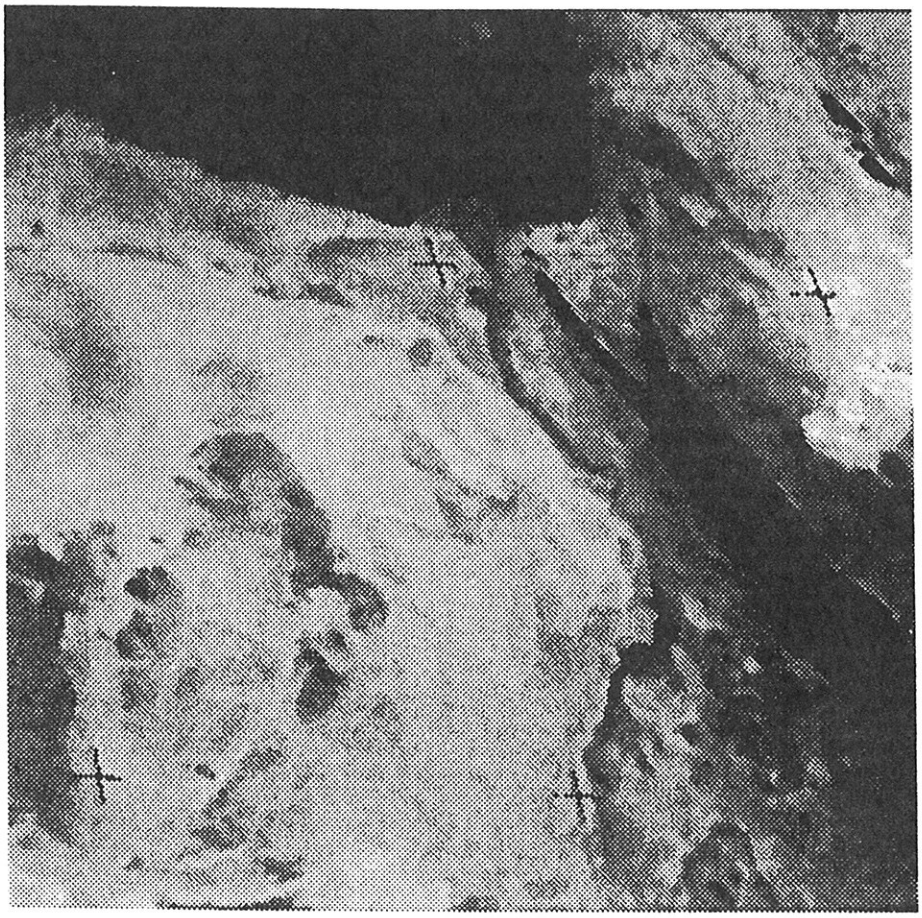

Figure 3 : *Image of the albedo of the ground in Egypt, computed from a time-series of Meteosat images. The darker the tone, the lower the albedo.*

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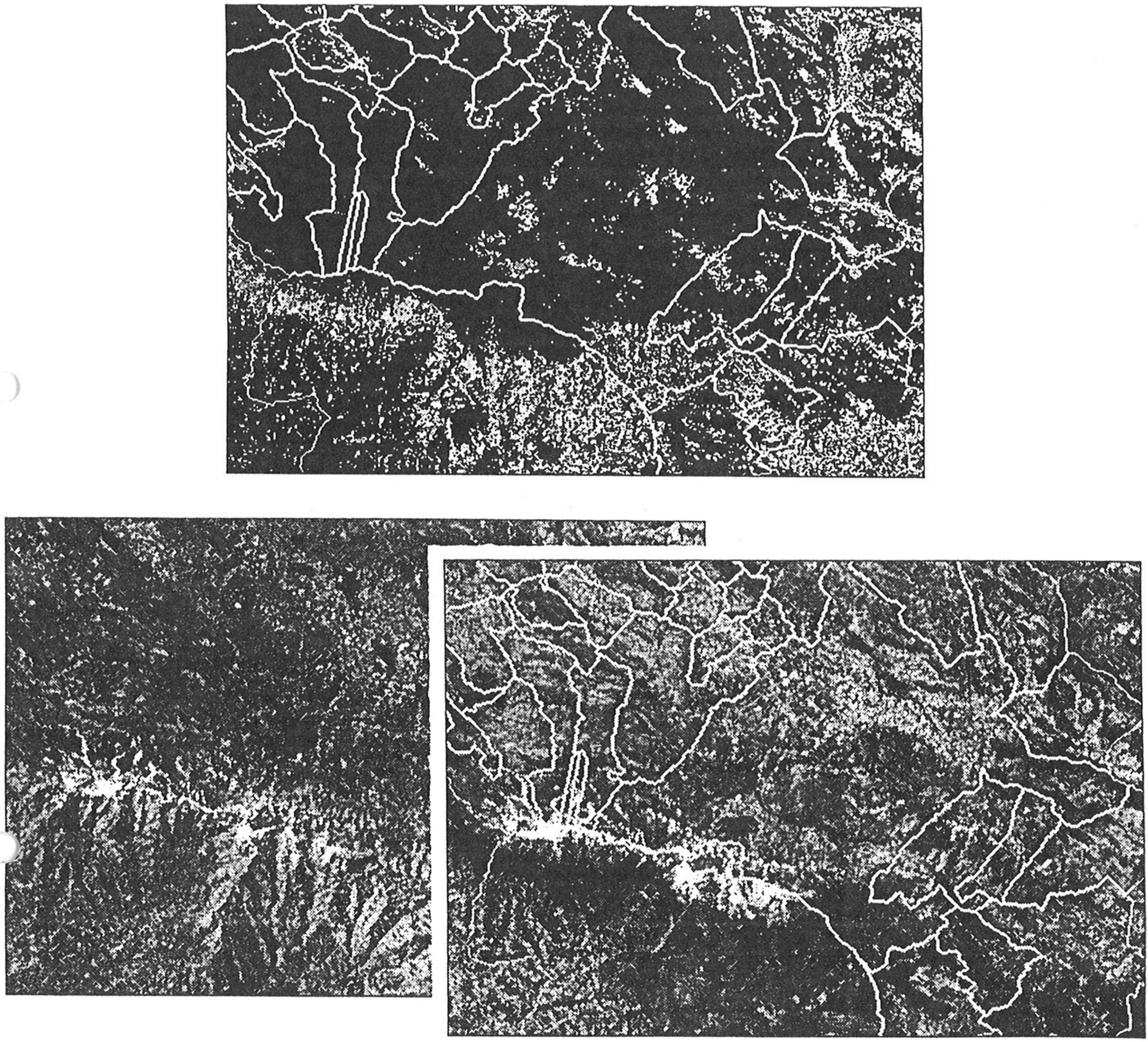

<u>Figure 4</u> : *Landsat/Multi-Spectral Scanner image of the region of Abruzzo (Italy). Two spectral images are presented. In one, district limits have been incrusted, which originate from digitized administrative maps. Processing of the spectral data provides a map related to the forest biomass available for energy conversion (in white and light grey).*

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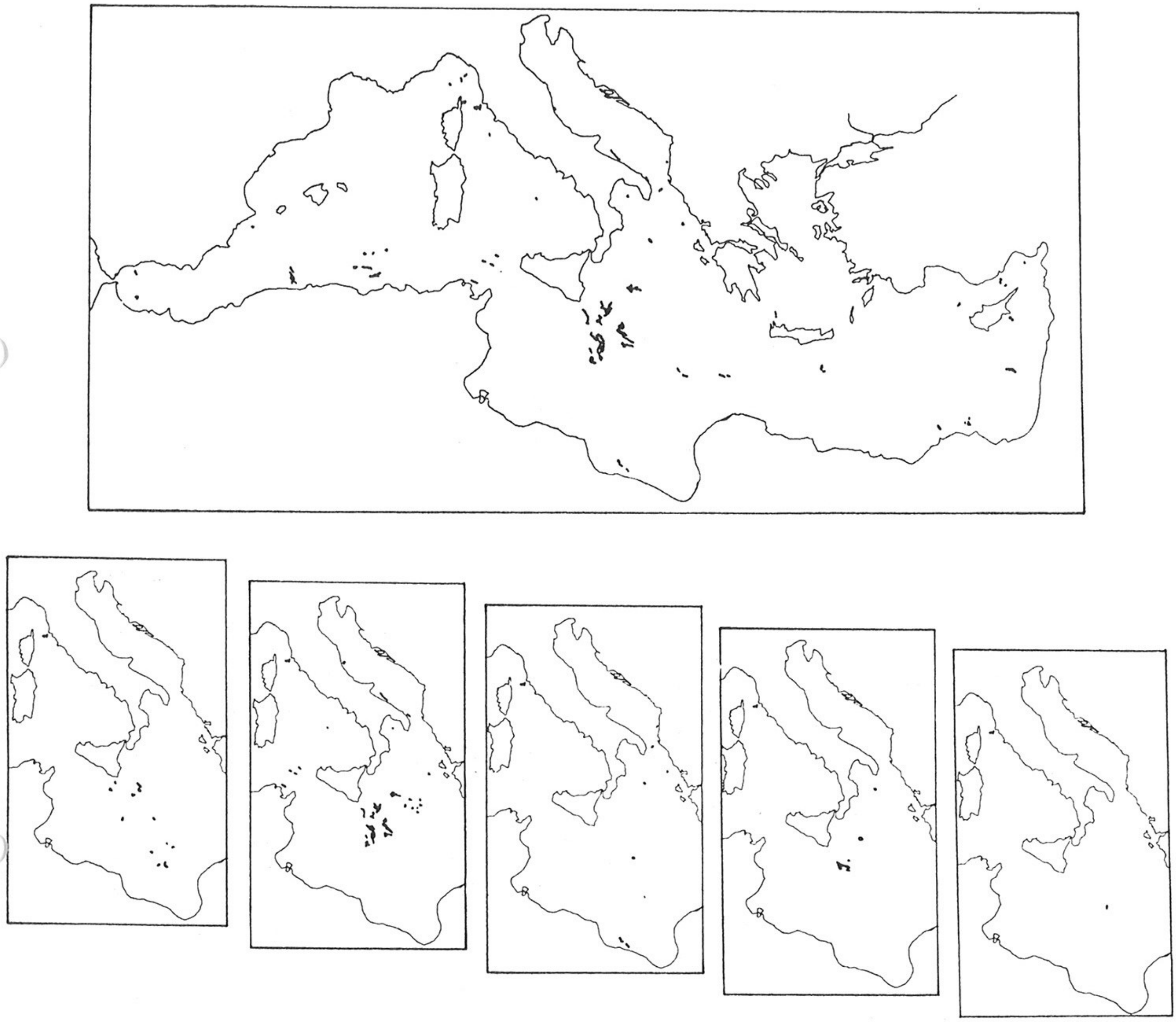

<u>Figure 5</u> : *Upper : Map of the oil spills detected in Landsat/MSS imagery during June 1981. The spills are drawn with the* ***same*** *scale than the coastline. Note how surfaces can be large.*
Lower : Bi-weekly evolution of the oil tankers unauthorized discharges in central Mediterranean Sea, beginning 6 May 1983.

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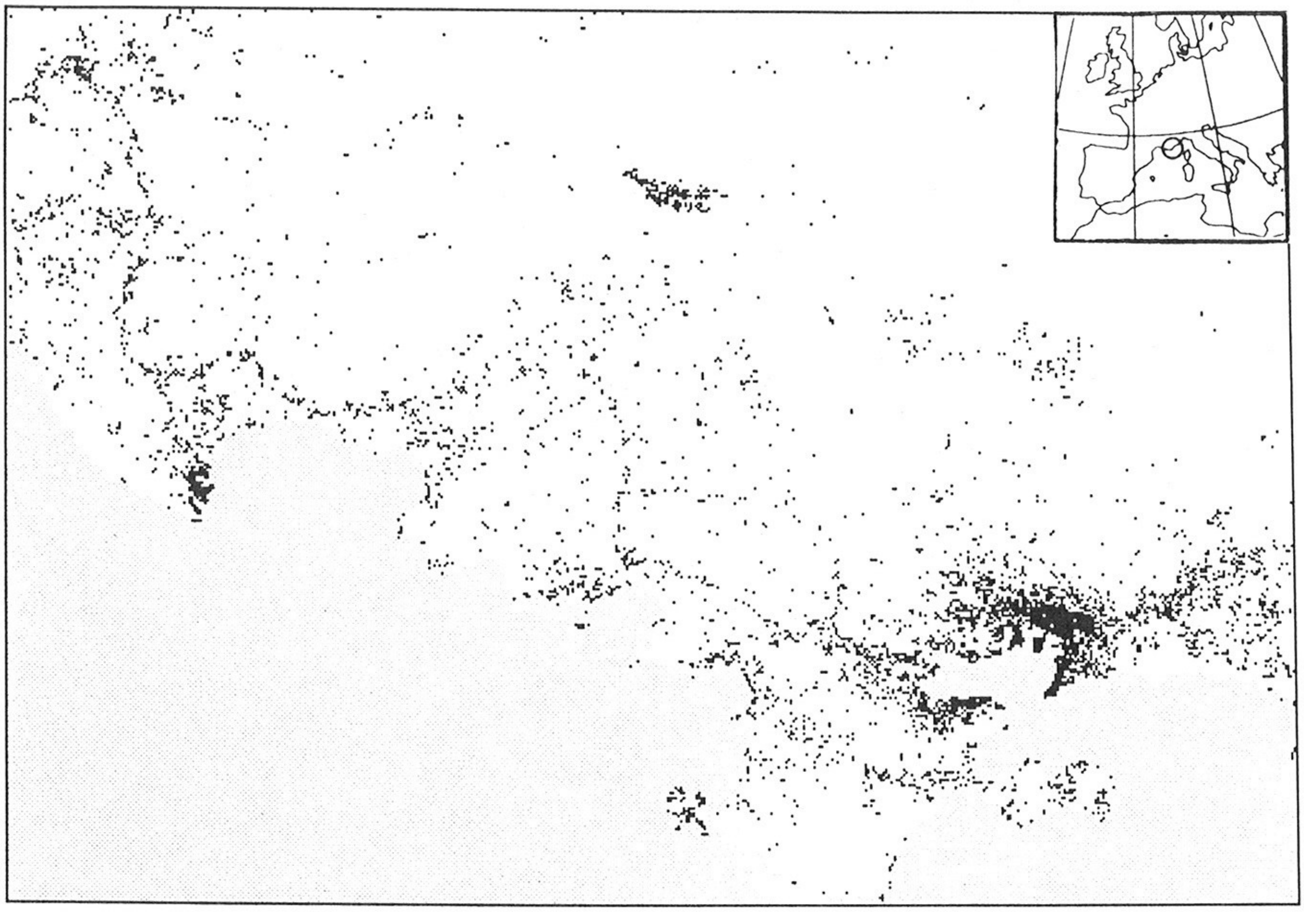

Figure 6 : Map of the urban area of a part of the French Riviera, in 1976. Three classes are displayed : sea (light grey), uninhabited areas (white), and urban areas (grey and black).

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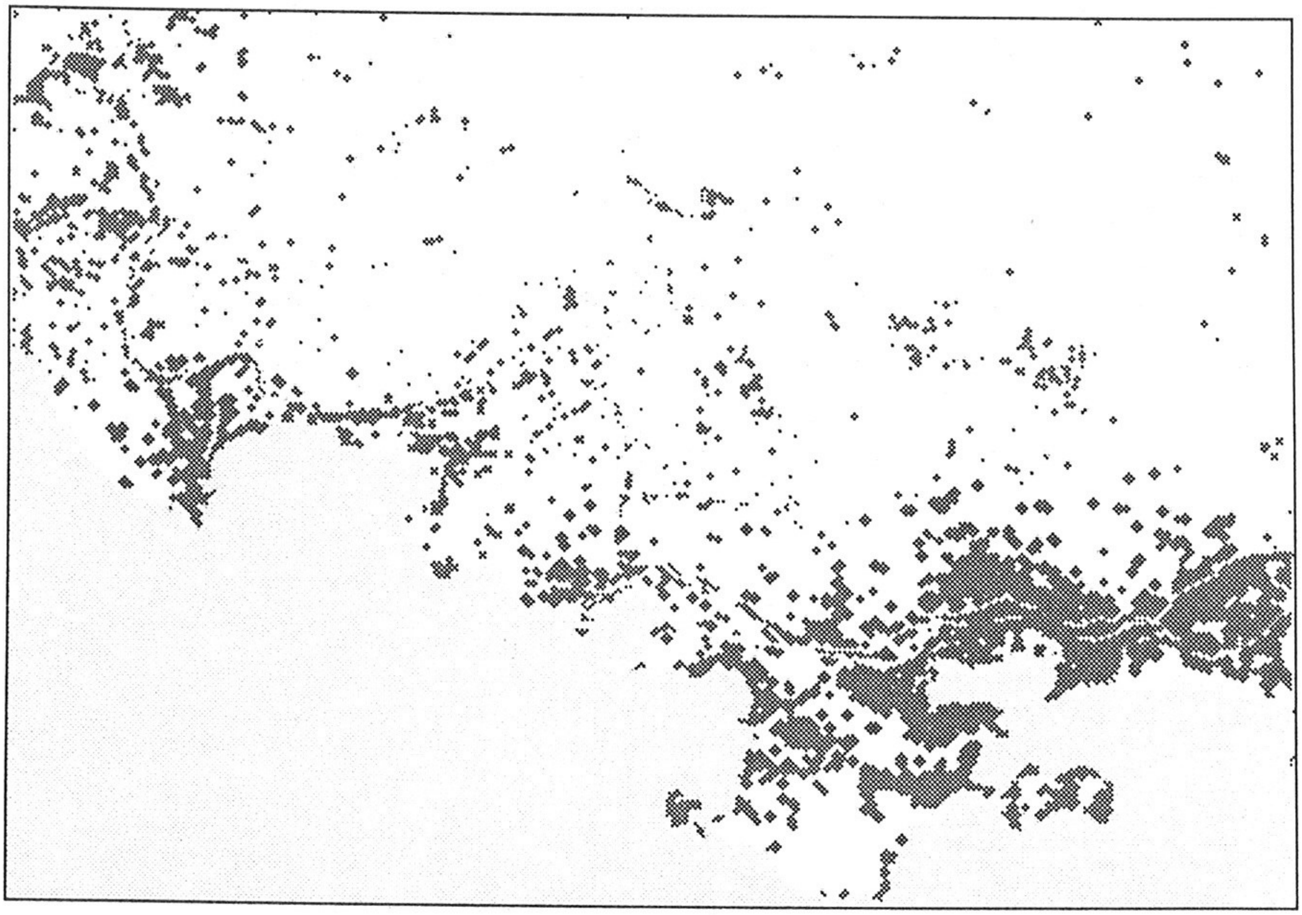

<u>Figure 7</u> : *Map of the urban area, predicted by the model for the year 2025. Three classes are displayed : sea (light grey), uninhabited areas (white), and urban areas (grey and black).*